

Spectra and elliptic flow for Λ , Ξ , and Ω in 200 A GeV Au+Au collisions

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Abstract. Using VISHNU hybrid model, we calculate the p_T -spectra and elliptic flow of Λ , Ξ , and Ω in 200 A GeV Au+Au collisions. Comparisons with the STAR measurements show that the model generally describes these soft hadron data. We also briefly study and discuss the mass ordering of elliptic flow among π , K , p , Λ , Ξ , and Ω in minimum bias Au+Au collisions.

1. Introduction

The main goal of relativistic heavy-ion collisions is to create the Quark-gluon Plasma (QGP) and study its properties. Due to their small hadronic cross sections, multi-strange hadrons, such as Ξ and Ω , experience early chemical and thermal freeze-out after hadronization [1, 2]. Their anisotropy flow are mainly developed in the QGP phase and less contaminated by the hadronic evolution, which are expected to provide valuable information for the QGP. In our early paper [2], the spectra and elliptic flow of strange and multi-strange hadrons at the LHC have been studied with VISHNU hybrid model. This proceeding will extend the calculations to top RHIC energies and compare the results with recent STAR data.

2. Setup of the calculations

VISHNU hybrid model [3] combines (2+1)-d relativistic viscous hydrodynamics (VISH2+1) [4] for the QGP fluid expansion with a microscopic hadronic transport model (UrQMD) [5] for the hadron resonance gas evolution. The hydrodynamic simulations input an equation of state (EoS) s95p-PCE constructed from recent lattice QCD data [6]. The transition from hydrodynamics to the hadron cascade is controlled by a switching temperature which is set at 165 MeV. We input smooth initial conditions that are generated from MC-Glauber model through averaging a large number of fluctuating initial entropy density profiles (Here, each initial density distribution is recentered and rotated to align the major and minor axes before averaging, which is called as *initialization in the participant plane*) [7]. Following [8, 9], we set the initial time $\tau_0 = 0.6$ fm/c, the specific shear viscosity $(\eta/s)_{QGP} = 0.08$ and specific bulk viscosity $(\zeta/s)_{QGP} = 0$. The normalization factor of the initial entropy density profiles is tuned to reproduce the final charged hadron multiplicity in the most central Au+Au collisions at $\sqrt{s_{NN}}=200$ GeV [10]. These inputs and settings once nicely described the p_T spectra and differential elliptic flow for all charged hadron and for pions and protons in 200 A GeV Au+Au collisions.

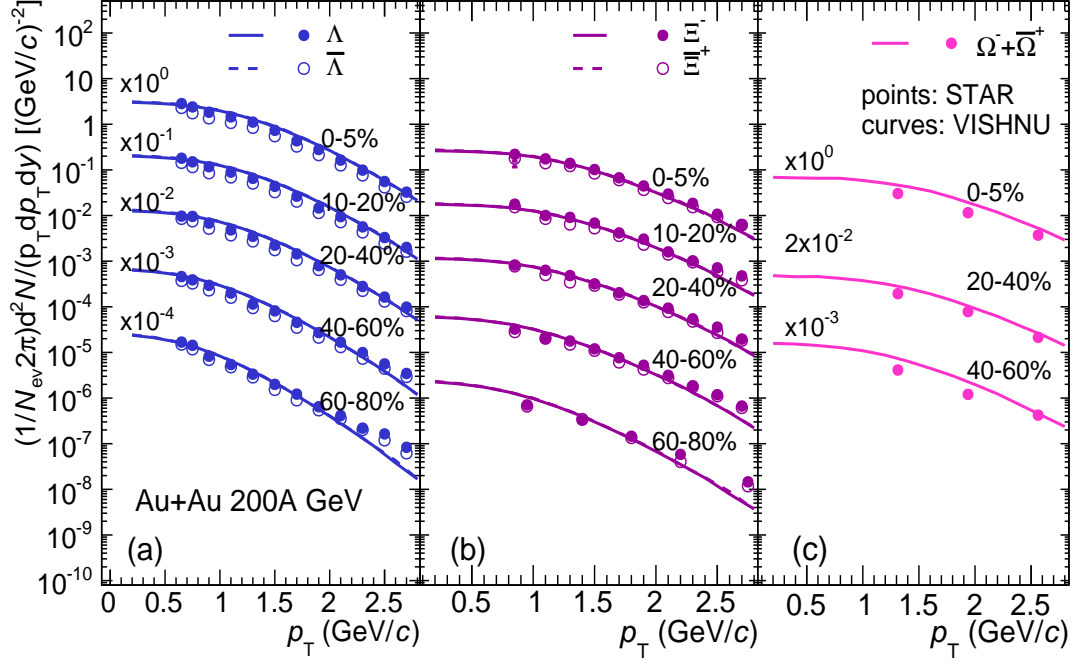


Figure 1. (Color online) Transverse momentum spectra of Λ , Ξ and Ω at various centralities in 200 A Au+Au collisions. Experimental data are from the STAR measurements [11]. Theoretical curves are calculated from VISHNU with MC-Glauber initial conditions, $\tau_0 = 0.6$ fm/c and $\eta/s = 0.08$.

3. Results

The p_T -spectra and elliptic flow of pions and protons in 200 A Au+Au collisions have been studied with VISHNU hybrid model in our early paper [3]. We showed that, with MC-Glauber initial conditions, $\tau_0 = 0.6$ fm/c and $\eta/s = 0.08$, VISHNU nicely describes these low p_T data of pions and protons at various centrality bins.

Figure 1 presents transverse momentum spectra of Λ , Ξ and Ω in 200 A GeV Au+Au collisions¹. In general, VISHNU describes the p_T -spectra of Λ and Ξ , but slightly over-predicts the production of Ω for all centrality bins. In spite of the normalization issues, VISHNU nicely fits the slope of the p_T -spectra for Λ , Ξ and Ω at various centralities. Together with the early nice descriptions of the p_T -spectra for pions, kaons and protons [8], it indicates that VISHNU generates a proper amount of radial flow during the QGP and hadronic evolution at the top RHIC energy.

Figure 2 shows the differential elliptic flow of Λ , Ξ and Ω in 200 A GeV Au+Au collisions. The theoretical curves are calculated from VISHNU using smooth initial conditions from MC-Glauber (with an average in participant plane). The STAR data are measured by the event plane method [11, 12], which contain the contributions from event-by-event fluctuations and the non-flow effects. To account the fluctuation contributions, we divide the flow data by $\langle \varepsilon_{\text{part}}^\alpha \rangle^\alpha$ and the theoretical results by $\bar{\varepsilon}_{\text{part}}$, where the exponent α depends on the event-plane resolution R and details of the v_2 extraction method [8, 13]. The detail values of $\langle \varepsilon_{\text{part}}^\alpha \rangle^\alpha$ and $\bar{\varepsilon}_{\text{part}}$ can be found in [8]. Our past research has shown that VISHNU nicely fits the elliptic flow for all charged

¹ For the STAR measurement, the Λ spectra has been corrected with the feed-down contributions from weak decays. Λ , Ξ and Ω from VISHNU are final hadrons after collisions and strong resonance decays since the UrQMD hadronic evolution does not contain any weak decay channels.

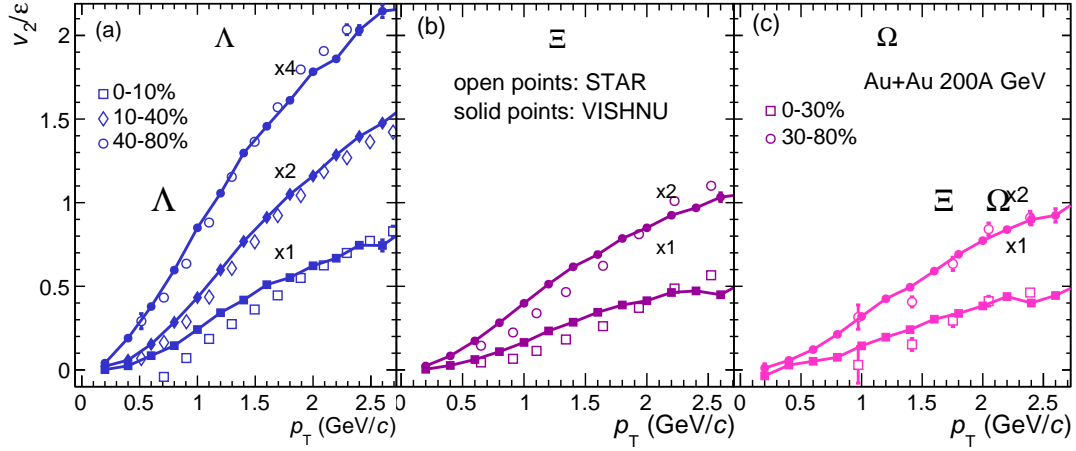


Figure 2. (Color online) Differential elliptic flow of Λ , Ξ and Ω in 200 A GeV Au+Au collisions. Experimental data are from STAR [11, 12], theoretical curves are calculated from VISHNU with the same inputs as for Fig. 1.

hadrons and for identified hadrons π and p in 200 A GeV Au+Au collisions with MC-Glauber, $\tau_0 = 0.6$ fm/c and $\eta/s = 0.08$ [8]. With the same inputs, we extend the VISHNU calculations for the strange and multi-strange hadrons with high statistical simulations. Fig. 2 shows that, VISHNU generally fits the elliptic flow of Λ , Ξ and Ω in 200 A GeV Au+Au collisions. For 0-10% centrality, the VISHNU results are slightly above the data for all three hadrons. It is worthwhile to mention that, for 2.76 A TeV Pb+Pb collisions, early VISHNU calculations also slightly over-predict the elliptic flow of Λ , Ξ and Ω at 10-20% and 30-40% centralities. In fact, the UrQMD simulations in VISHNU assigns small cross-sections to Ξ and Ω , leading to an early decoupling of these two hadrons. Compared with pure hadronic simulations [15], this leads to an insufficient development of elliptic flow for these two multi-strange hadrons in central and semi-central collisions at top RHIC and the LHC energies.

It is generally believed that the mass ordering of elliptic flow among various identified hadrons reflects the interplay between radial and elliptic flows, providing more information on the QGP fireball evolution. Figure 3 presents the mass ordering of differential elliptic flow among π , K , p , Λ , Ξ , and Ω in minimum bias Au+Au collisions. Compared with the STAR measurements, VISHNU correctly describes the v_2 mass ordering among π , K , p , and Ω , but fails to reproduce the mass ordering of Λ and Ξ . In our early investigations [2, 16], a similar situation was found in 2.76 A TeV Pb+Pb collisions at 10-20% and 40-50% centralities. Although VISHNU correctly generates the v_2 mass ordering among π , K , p , it slightly under-predicts the proton v_2 at lower transverse momentum. Together with the slightly over-predictions of the Λ and Ξ data, this leads to an inverse v_2 mass-ordering among p , Λ and Ξ . The effects from the initial flow or improved UrQMD hadronic cross-sections may solve this issue within the framework of VISHNU, which should be investigated in the near future.

4. Summary

In this proceeding, we present VISHNU calculations on the soft hadron data of strange and multi-strange hadrons in 200 A GeV Au+Au collisions. With the parameter settings used in our early calculations, VISHNU generally describes the p_T -spectra and elliptic flow of Λ , Ξ and Ω for various centrality bins. We also compare the v_2 mass ordering among π , K , p , Λ , Ξ , and Ω with the STAR measurements and find that VISHNU correctly describes the v_2 mass ordering among π , K , p , and Ω , but fails to reproduce the mass ordering among p , Λ , and Ξ .

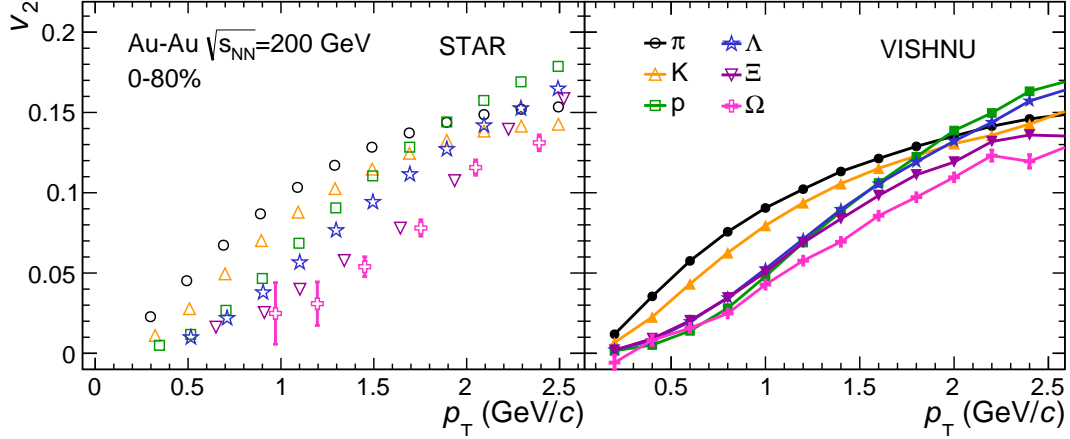


Figure 3. (Color online) Differential elliptic flow of π , K , p , Λ , Ξ , and Ω in minimal bias Au+Au collisions. Left panel: STAR measurements [12, 14], right panel: VISHNU calculations.

Acknowledgments

We thank X. Zhu and S. Shi for helpful discussion. This work was supported by the NSFC and the MOST under Grants No. 11435001 and No. 2015CB856900. X.Z. was also partially supported by the China Postdoctoral Science Foundation under Grant No. 2015M570879. We gratefully acknowledge extensive computing resources provided to us on Tianhe-1A by the National Supercomputing Center in Tianjin, China.

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